TITLE OF THE INVENTION

EXPOSURE APPARATUS AND METHOD, DEVICE MANUFACTURING METHOD, AND DISCHARGE LAMP

BACKGROUND OF THE INVENTION

This invention relates to an exposure apparatus and exposure method ideal for manufacturing a semiconductor device, a discharge lamp employed as a light source in the apparatus, and a method of manufacturing a device using the exposure apparatus.

An optical unit in an exposure apparatus used to manufacture a semiconductor device has an illuminating optical unit for illuminating a reticle, which possesses a pattern, with exposing light, and a projection optical unit for projecting and imaging the reticle pattern on a wafer substrate. The illuminating optical unit is equipped with a light source that produces the exposing light, and a mercury-vapor lamp (discharge lamp) for generating i line light or g line light is used widely as the exposing light source.

Since a high-output discharge lamp used in an exposure apparatus has a short life, it is required that the lamp be replaced periodically depending upon the operating time of the exposure apparatus. For this

reason, the light source is provided with a holder, such as a socket, for holding the discharge lamp in a removable manner in order to facilitate replacement.

A variety of improvements have resulted in the recent development of discharge lamps having various capabilities and there has been an increase in the types thereof available.

Because discharge lamps have not been strictly standardized, the specifications thereof differ from maker to maker and lamp characteristics differ slightly depending upon the type. Examples of differences in characteristics include disparities in optimum cooling conditions, allowable power range and the shape of the minute arc (arc shape at the light-emitting point of the lamp) produced. Though no problems arise if a discharge lamp intended for the exposure apparatus is used, when making a replacement, but there are instances where replacing an old discharge lamp with a new discharge lamp of a different type results in a mismatch of characteristics.

Though it may be possible to have a maintenance expert check the type of discharge lamp and set newly optimum conditions suited to the discharge lamp, making such setting whenever a discharge lamp is replaced is troublesome and leads to increased servicing labor. Moreover, if the person performing such maintenance

misidentifies the type of discharge lamp and makes the wrong setting, the exposure apparatus may operate with the wrong characteristics and fail to manifest the desired exposure performance.

For example, assume that a discharge lamp is not subjected to optimum cooling. If the lamp is cooled excessively, difficulties such as failure to obtain the desired spectral power may occur. Additionally, if the discharge lamp is cooled inadequately, its temperature will rise and this can seriously shorten the life of the discharge. Further, if power in excess of the maximum allowable power of the discharge lamp is applied thereto owing to an erroneous setting, this can shorten the life of the device (discharge lamp). If the shape of the arc of the discharge lamp does not match the hypothetical design value of the illuminating optical unit, this can result in failure to obtain the desired illuminating light on the reticle and cause a decline in exposure transfer precision.

SUMMARY OF THE INVENTION

Accordingly, a prime object of the present invention is to provide an exposure apparatus and method capable of flexibly supporting discharge lamps of a variety of different types.

Another object of the present invention is to provide a discharge lamp that can be adapted to an exposure apparatus mentioned above.

A more specific object of the present invention is to provide an exposure apparatus and method in which it is possible to identify the type of discharge lamp and identifies settings suited to the discharge lamp, as well as a discharge lamp that makes this possible.

A further object of the present invention is to provide an outstanding device manufacturing method that uses the exposure apparatus mentioned above.

According to the present invention, the foregoing objects are attained by providing an exposure apparatus and method, a device manufacturing method using this exposure apparatus, and a discharge lamp constructed as set forth below.

Specifically, the present invention provides an exposure apparatus using a discharge lamp as a light source, the exposure apparatus having a sensor for recognizing the type of discharge lamp mounted in a holder or recognizing whether a discharge lamp has been mounted in the holder.

Alternatively, the present invention provides an exposure apparatus using a discharge lamp as a light source, the exposure apparatus having means for setting at least one of optical conditions, power source

conditions and cooling conditions in dependence upon the type of discharge lamp mounted.

Further, the present invention provides a device manufacturing method using the exposure apparatus which includes steps of preparing the exposure apparatus and performing exposure using the exposure apparatus.

Further, the present invention provides an exposure method using a discharge lamp as a light source, the exposure method including steps of recognizing the type of discharge lamp and automatically setting at least one of optical conditions, power source conditions and cooling conditions based upon the recognition made.

Further, the present invention provides a discharge lamp used as a light-emitting source of a light source device, the discharge lamp having a mark or shape capable of being recognized by a sensor when the discharge lamp is used in the device.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for setting at least one of optical conditions, power-source conditions and cooling conditions, which conform to the type of discharge lamp mounted, based upon the recognition made.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for changing optical conditions of an

optical illuminating unit in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus changes the optical conditions by adjusting a zoom lens of the illuminating optical unit in accordance with the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, adjusting the zoom lens optimizes the shape of the image of an arc produced by the discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for changing the power-source conditions by setting allowable power applied to the discharge lamp in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for changing discharge-lamp cooling performance in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for cooling the mounted discharge lamp by a gas.

In accordance with a preferred embodiment of the

present invention, a sensor is provided in the vicinity of the holder and senses a characterizing portion formed on the discharge lamp held by the holder.

In accordance with a preferred embodiment of the present invention, the sensor of the exposure apparatus senses the characterizing portion optically, magnetically, mechanically or through use of pressure.

In accordance with a preferred embodiment of the present invention, the characterizing portion is a groove or hole formed in the discharge lamp in the vicinity of a location at which the discharge lamp is held by the holder.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for allowing an operator to input the type of discharge lamp mounted or for recognizing the type of discharge lamp automatically.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes memory means for storing types of discharge lamps and setting conditions suited thereto, wherein optical conditions, power source conditions and cooling conditions conforming to the type of mounted discharge lamp are set based upon content of the memory means.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further

includes means for changing optical conditions of an illuminating optical unit in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus changes the optical conditions by adjusting a zoom lens of the illuminating optical unit in accordance with the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, adjusting the zoom lens by the exposure apparatus optimizes the shape of the image of an arc produced by the discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for changing the power source conditions by setting allowable power applied to the discharge lamp in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for changing discharge-lamp cooling performance in dependence upon the type of discharge lamp.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for cooling the mounted discharge lamp by a gas.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for inhibiting firing of the discharge lamp and/or for issuing a warning in a case where the type of discharge lamp cannot be recognized.

In accordance with a preferred embodiment of the present invention, the exposure apparatus further includes means for inhibiting application of voltage and/or for issuing a warning in a case where a discharge lamp has not been mounted in a mounting portion.

In accordance with a preferred embodiment of the present invention, the exposure method further includes a step of inhibiting firing of the discharge lamp and/or issuing a warning in a case where the type of discharge lamp cannot be recognized.

In accordance with a preferred embodiment of the present invention, the exposure method further includes a step of sensing whether a discharge lamp has been mounted and inhibiting firing of the discharge lamp and/or issuing a warning in a case where a discharge lamp has not been mounted.

In accordance with a preferred embodiment of the present invention, a discharge lamp used as the light source of the exposure apparatus has a mark or shape capable of being recognized by a sensor when the discharge lamp is used in an exposure apparatus.

In accordance with a preferred embodiment of the present invention, the discharge lamp used as the light source of an exposure apparatus uses any of a three-dimensional shape, planar shape, pattern, coloring, reflectivity and audio as the mark or shape.

In accordance with a preferred embodiment of the present invention, the discharge lamp used as the light source of the exposure apparatus is formed to have a groove or hole capable of being sensed by a sensor provided in the vicinity of a holder of the discharge lamp.

In accordance with a preferred embodiment of the present invention, the mark or shape with which the discharge lamp is provided to achieve a plurality of applications.

In accordance with a preferred embodiment of the present invention, the plurality of applications are identifying the type of discharge lamp, identifying whether a discharge lamp is mounted or not, or cooling the discharge lamp.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is diagrammatic view showing primarily the illuminating unit of a semiconductor exposure apparatus;

Fig. 2 is a diagrammatic view of a discharge lamp;

Fig. 3 is an enlarged view of a portion for mounting the discharge lamp;

Fig. 4 is a diagram showing the relationship between the discharge lamp mounting portion and a support column for supporting the discharge lamp;

Fig. 5 is a diagram showing another mode of Fig. 4;

Fig. 6 is a diagram showing flow of manufacture of a microdevice; and

Fig. 7 is a diagram illustrating the detailed flow of a wafer process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail in accordance with the

accompanying drawings.

<Exposure Apparatus>

An embodiment of an exposure apparatus according to the present invention will now be described with reference to the drawings, in which Fig. 1 is a diagrammatic view showing primarily the illuminating unit of a semiconductor exposure apparatus.

As shown in Fig. 1, the semiconductor exposure apparatus includes a discharge lamp 1 serving as a light-emitting source used as the light source of the apparatus. By way of example, the discharge lamp is a high-voltage mercury-vapor lamp that generates i line light or g line light. The apparatus further includes an elliptical mirror 2 for collecting the ray from the discharge lamp 1; a first zoom lens 3 for projecting the image of the arc of the discharge lamp 1, which image formed on a second focal point of the elliptical mirror 2, onto an input section of a fly eye's lens 7 upon changing the size of the image; a motor 4 for driving the first zoom lens 3; an optical filter 5 for transmitting only a specific wavelength; a reflecting mirror 6; the fly eye's lens 7; an aperture 8 for deciding the effective shape of the light source; a condenser lens 9; a masking plate 10, which is located at a reticle conjugate point, for limiting the exposure area on a reticle 12; and relay lenses 11. These

elements construct an illuminating optical unit.

The apparatus further includes the reticle (also referred to as a mask) 12, which possesses a circuit pattern; a projecting optical unit 13; and an exposure substrate 14, such as a semiconductor wafer or glass substrate. The reticle pattern is projected upon the substrate 14 at a prescribed demagnification by the projecting optical unit 13 so that the pattern is transferred to the substrate by exposure.

The apparatus further includes a discharge lamp mounting portion 15 serving as a holder for fixedly holding the discharge lamp 1; a starter 16 for generating a high voltage when the discharge lamp 1 is fired; a power source 17 for supplying the discharge lamp 1 with power; a controller 18 for controlling the semiconductor exposure apparatus; a driver 19 that drives the motor 4 for the first zoom lens; input means (an input terminal) 25 that allows the operator to enter the type of discharge lamp mounted; and memory means 26 for storing types of discharge lamps that can be used, as well as optimum conditions under which each of the discharge lamps may be used.

The apparatus further includes a blower 20 for cooling the vicinity of the light-emitting portion of the discharge lamp by blowing a gas (clean dry air) directly at the light-emitting portion; diaphragms 21,

22; pressure sensors 23, 24; a passageway 30 on the side on which the dry air is supplied; and passageways 31, 32 for the clean dry air that has passed through the diaphragms 21, 22. These components construct cooling means for the discharge lamp. The cooling performance for cooling the discharge lamp can be set freely by adjusting the diaphragms 21, 22 to vary the amount of air blown from the blower 20.

The signal lines include a feeder line a for supplying power from the power source 17 to the starter 16; a power command line b for sending a power command from the controller 18 of the semiconductor exposure apparatus to the power source 17; a firing command line c for sending a firing command from the controller 18 of the semiconductor exposure apparatus to the power source 17; a drive command line d for sending a drive command from the controller 18 of the driver 19; and a drive line e from the driver 19 to the motor 4 for driving the first zoom lens. Further, f and g denote contact input signals from pressure sensors 23, 24.

The details of the discharge lamp will be described with reference to Fig. 2. As shown in Fig. 2, the discharge lamp includes an anode 40, a cathode 41, a bulb 42, an anode base 43, a cathode base 44, a support column 45 secured to a support portion, an anode line 46, and a cathode line 47. The shape (arc shape) of the

light-emitting point of the discharge lamp is determined by the positions and shapes of the anode 40 and cathode 41 and by the spacing between them.

One characterizing feature of this embodiment is that an annular groove 48 is formed in the support column 45 at a specific position (height). As will be described later, the groove 48 has two functions, namely a marking function for identifying the type of discharge lamp or for determining whether a discharge lamp has been mounted or not, and a cooling-groove function for passing the cooling gas (clean dry air) that cools the discharge lamp. The cross sectional area of the groove or the position at which it is formed is changed depending upon the type of discharge lamp.

Fig. 3 is an enlarged view of the portion for mounting the discharge lamp as seen from the side. The groove 48 for allowing the passage of air is provided at a specific position of the support column 45 of discharge lamp 1, and the passageways 31, 32 through which the air flows are provided at specific positions of the discharge lamp mounting portion 15. As shown in Fig. 3, the passageway 31 passes air for cooling the discharge lamp 1 and the passageway 32 is for recognizing whether the discharge lamp 1 has been mounted. In Fig. 3, only the upper passageway 31 coincides with the groove 48 of the discharge lamp.

More specifically, the passageway 31 is open owing to coinside with the groove 48. The pressure within passageway 31, therefore, declines. The passageway 32, on the other hand, is closed and its internal pressure therefore is higher than the pressure in passageway 31.

Fig. 4 is an enlarged top view showing the relationship between the discharge lamp mounting portion 15 and a portion in which the support column 45 of the discharge lamp 1 is inserted and fixed. The view of Fig. 4 is taken in the horizontal plane of the groove 48. The dashed line in Fig. 4 indicates the contour of the outer periphery of the support column 45, and the circular area (shaded) bounded by the solid line within the dashed line indicates the cross section of the groove 48. Cooling air that flows into the passageway 31 flows along the groove 48 as indicated by the arrows. The air is introduced to the blower 20 serving as the means for cooling the discharge lamp, thereby cooling the vicinity of the light-emitting point, where the temperature of the discharge lamp is highest.

In a modification, the support column of the discharge lamp is provided with a through-hole 49 instead of the groove-shaped air passageway, as shown in Fig. 5, and the discharge lamp mounting portion is provided with a semicircular groove. In this case the air flows through the through-hole 49 in the manner

illustrated by the arrow.

According to the present embodiment, a maintenance worker mounts the discharge lamp 1 in the discharge lamp mounting portion 15 and then is capable of entering the type of mounted discharge lamp using the input means 25. When the type of the discharge lamp 1 has been entered by the input means 25, the controller 18 compares this with information that has been stored in the memory means 26. In a case where the result of the comparison indicates that the entered type of discharge lamp is not registered in the memory means 26, a firing command will not be sent to the power source 17, thereby inhibiting firing of the discharge lamp, even if the worker attempts to send such a command. At the same time, a warning indication is presented to the worker to inform the worker that the type of discharge lamp has not been registered. The input means 25 has a function for registering discharge lamps of new type. Even if a new type of discharge lamp becomes available, therefore, the discharge lamp can be used under optimum conditions once it has been registered.

In a case where the result of the comparison indicates that the entered type of discharge lamp has already been registered in the memory means 26, the optimum conditions under which this discharge lamp can be used is read out of the memory means 26 and at least

one, and preferably two or more, of the following conditions of use is set by the worker:

(1) Optical condition of the illuminating optical unit

The driver motor 4 is driven to change the lens position of the first zoom lens 3 in dependence upon the mounted discharge lamp in such a manner that the shape of the arc of the mounted discharge lamp will assume the optimum shape on the incidence side of the fly eye's lens 7.

(2) Power-source conditions of discharge lamp

The power conditions (maximum value of power introduced, allowable range, etc.) of the mounted discharge lamp are changed in dependence upon the type of discharge lamp. If a power value that exceeds a tolerance value has already been set, then this value is changed to a safe value.

(3) Cooling conditions of discharge lamp

Since the amount of air blown from the blower 20 can be adjusted by adjusting the diaphragms 21, 22, the amount of blown air is altered in dependence upon the type of mounted discharge lamp to establish the optimum cooling performance.

According to this embodiment, the type of mounted discharge lamp can be recognized automatically using the groove of the discharge lamp 1 without requiring an

entry from the worker. The method will now be described.

With the discharge lamp 1 mounted in place as shown in Fig. 1, the states of the pressure sensors 23, 24 enter the controller 18 as the contact input signals f, g, respectively. As a result, the controller 18 detects the absence or presence of grooves at a plurality of specified positions of the discharge lamp support column and identifies the type of discharge lamp based upon the results of detection.

On the basis of the identification made, the controller 18 refers to the memory means 26 and sets at least one, and preferably two or more, of the optical conditions, power-source conditions and cooling conditions noted at (1) to (3) above.

In the event that the pressure sensors 23, 24 both sense low pressure, the controller 18 decides that a discharge lamp has not been mounted. Even if a worker should attempt to enter a discharge lamp firing command, the command will not be delivered to the power source 17 and, hence, the generation of high voltage will be inhibited. Conversely, in the event that the pressure sensors 23, 24 both sense high pressure, the controller 18 decides that an unidentifiable discharge lamp has been mounted. Even if a worker should attempt to enter a discharge lamp firing command, the command will not be

delivered to the power source 17 and, hence, firing of the discharge lamp will be inhibited. This eliminates that possibility that a malfunction will be caused by using a discharge lamp that does not satisfy the established conditions.

Thus, recognition of a mounted discharge lamp is performed merely by mounting the discharge lamp in the mounting portion, and optimum conditions of use conforming to the recognized discharge lamp can be set. Even if automatic recognition cannot be carried out, a worker can enter the type of discharge lamp or register a discharge lamp anew. The result is an exposure apparatus that makes it possible to deal with different types of discharge lamps in a flexible manner.

Other sensors such as optical, magnetic or mechanical sensors may be used instead of pressure sensors to identify the type of discharge lamp. In such case a discharge lamp would be provided with a characterizing portion (mark or shape) capable of being identified by the sensor. For example, a characterizing three-dimensional shape or planar shape, or a characterizing mark using a pattern, color, reflectivity or audio is conceivable. As a specific example of a feasible arrangement, a fiber sensor usable under conditions of high temperature can be employed as a sensor, a groove or hole can be provided on the

discharge lamp side at a position sensed by the fiber sensor, or the reflectivity of this location can be changed. In a case where a sensor other than a pressure sensor is used to recognize the type of discharge lamp, there is the possibility that sensing precision will be adversely affected because of high temperature produced when the discharge lamp is lit. However, this problem can be avoided if sensing is performed by bringing the sensor close to the discharge lamp in the cool period before the lamp is fired and then separating the sensor from the lamp after it is fired.

In accordance with the foregoing embodiment, the apparatus is provided with input means by which an operator may enter the type of discharge lamp mounted, or with means for identifying the type of discharge lamp automatically. At least one of optical conditions, power-source conditions and cooling conditions is selected in dependence upon the type of discharge lamp. As a result, different discharge lamps can be used under conditions that are optimum for these discharge lamps, thus making it possible to provide an exposure apparatus having a high degree of universality.

Further, if a characterizing mark or shape capable of being identified by a sensor is provided on a discharge lamp and the type of discharge lamp is recognized by the sensor, at least one of optical

conditions, power-source conditions and cooling conditions can be set automatically in dependence upon the type of discharge lamp recognized. As a result, it is possible to provide an exposure apparatus exhibiting a high productivity and featuring low maintenance cost.

Furthermore, it is possible to automatically recognize the fact that a discharge lamp has not been mounted or that a discharge lamp whose type is not identifiable has been mounted. This makes it possible to provide a reliable and highly stable exposure apparatus in which the unnecessary generation of a high voltage at a starter output to initiate a discharge can be avoided.

Furthermore, the support column of a discharge lamp is provided with a groove or hole through which a gas is capable of passing, and the type of discharge lamp, or whether or not, a discharge lamp has been mounted, is determined based upon the pressure of the gas. This assures more reliable cooling and makes it possible to identify a discharge lamp with greater certainty.

Furthermore, a discharge lamp is formed to have a mark or shape that can be identified by a sensor at the time of use. The mark or shape has a plurality of uses, such as allowing identification of the discharge lamp, determination as to whether a discharge lamp has been mounted or not, and cooling of the discharge lamp. This

makes it possible to provide a discharge lamp having a high added value at low cost.

<Device manufacturing method>

An embodiment of a method of manufacturing a device utilizing the above-described exposure apparatus will now be set forth.

Fig. 6 is a diagram showing the flow of manufacture of a microdevice (a semiconductor chip such as an IC or LSI chip, a liquid crystal panel, a CCD, a thin-film magnetic head, a micromachine, etc.). The pattern for the device is designed at step 1 (circuit design). A mask on which the designed circuit pattern has been formed is fabricated at step 2 (mask fabrication). Meanwhile, a wafer is manufactured using a material such as silicon or glass at step 3 (wafer manufacture). The actual circuit is formed on the wafer by lithography, using the mask and wafer that have been prepared, at step 4 (wafer process), which is also referred to as a "pre-process". A semiconductor chip is obtained, using the wafer fabricated at step 4, at step 5 (assembly), which is also referred to as a "post-process". This step includes steps such as actual assembly (dicing and bonding) and packaging (chip encapsulation). The semiconductor device fabricated at step 5 is subjected to inspections such as an operation verification test and durability test at step 6 (inspection). The

semiconductor device is completed through these steps and then is shipped (step 7).

Fig. 7 is a flowchart illustrating the detailed flow of the wafer process mentioned above. The surface of the wafer is oxidized at step 11 (oxidation). An insulating film is formed on the wafer surface at step 12 (CVD), electrodes are formed on the wafer by vapor deposition at step 13 (electrode formation), and ions are implanted in the wafer at step 14 (ion implantation). The wafer is coated with a photoresist at step 15 (resist treatment), the wafer is exposed to the circuit pattern of the mask to print the pattern onto the wafer by the above-described projection exposure apparatus at step 16 (exposure), and the exposed wafer is developed at step 17 (development). Portions other than the developed photoresist are etched away at step 18 (etching), and unnecessary resist left after etching is performed is removed at step 19 (resist removal). Multiple circuit patterns are formed on the wafer by implementing these steps repeatedly.

If the production process using this embodiment is employed, highly precise devices can be manufactured at low cost. Manufacture of such devices using the prior-art techniques was difficult.

Thus, in accordance with the present invention, as described above, it is possible to provide a highly

universal exposure apparatus and method that make it possible to deal with different types of discharge lamps in a flexible manner. In addition, discharge lamps adaptable to this exposure apparatus can be provided. If devices are manufactured using this exposure apparatus, they can be manufactured at a cost lower than that achievable heretofore.

The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore, to apprise the public of the scope of the present invention, the following claims are made.